eRD16: Forward/Backward Tracking at EIC using MAPS Detectors

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Abstract:

We propose continued conceptual development of tracking stations with silicon-sensors near the collision vertex to detect the scattered electron and produced secondary hadrons at forward and backward angles with respect to the EIC beams. The focus is on disks with thinned-silicon sensors with the overall goal to arrive at science-driven sensor specifications, optimized geometrical configuration of the forward/backward disks, disk layout, conceptual arrangement of services, and integration with tracking subsystems covering the central barrel region. Part of this work is being pursued in collaboration with eRD18, which focuses on sensor development and mid-rapidity (vertex) tracking.

Outline

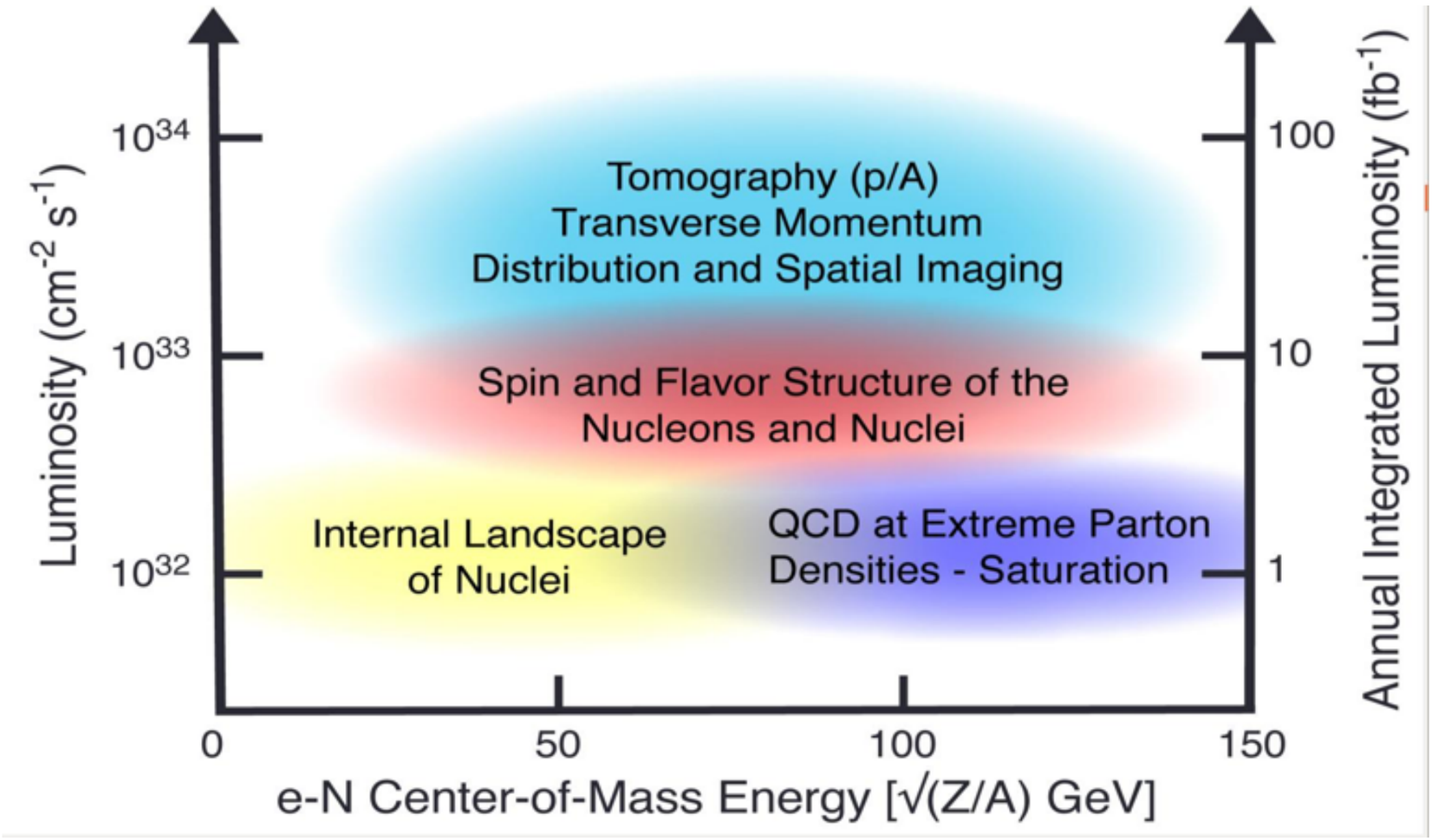
- Introduction
  - RNC physics interests in EIC
  - Instrumentation efforts in relation to EIC

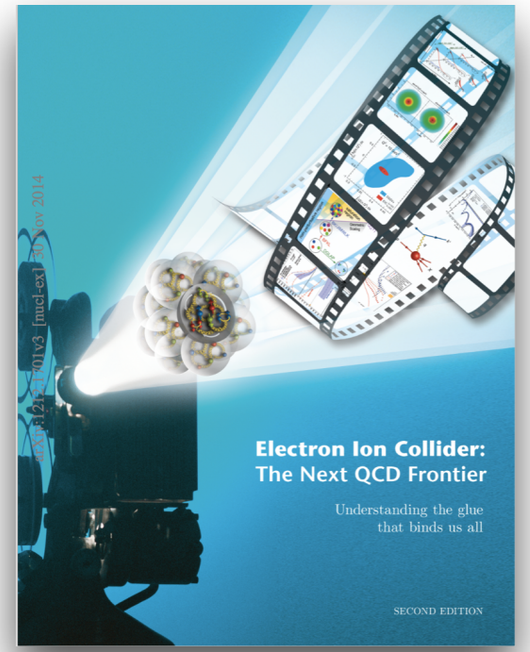
- Simulation progress,
  - Tools used,
  - Selected topics and results

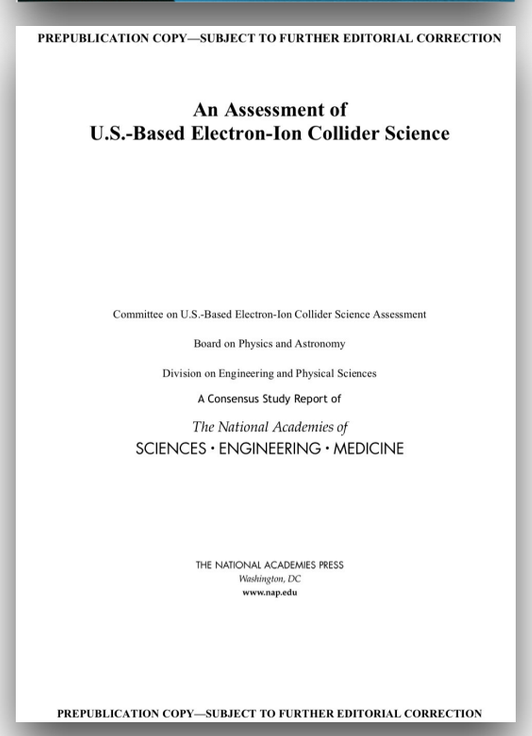
- Proposed effort
  - Simulation studies and development,
  - Start on investigating services,
  - Collaboration with eRD18,
  - Request

RNC - EIC Science Interests

Interest in *gluon-dense matter:*

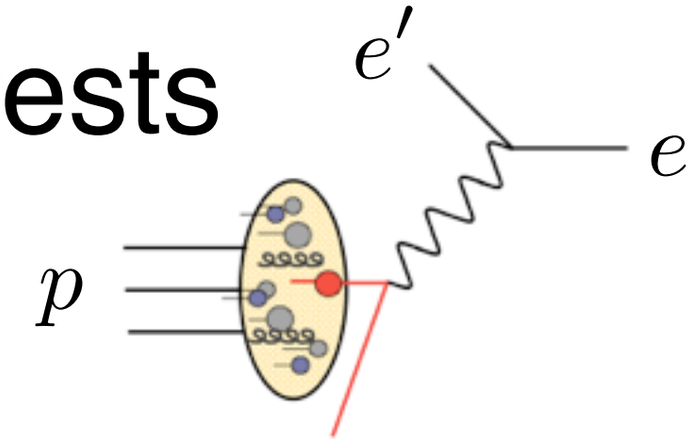






implies a need for *high*-√s,
observables $F_2(x,Q^2)$, $F_L(x,Q^2)$, $g_1(x,Q^2)$ at *low*-x
+ diffraction, dijets, heavy flavor, …

RNC - EIC Science Interests



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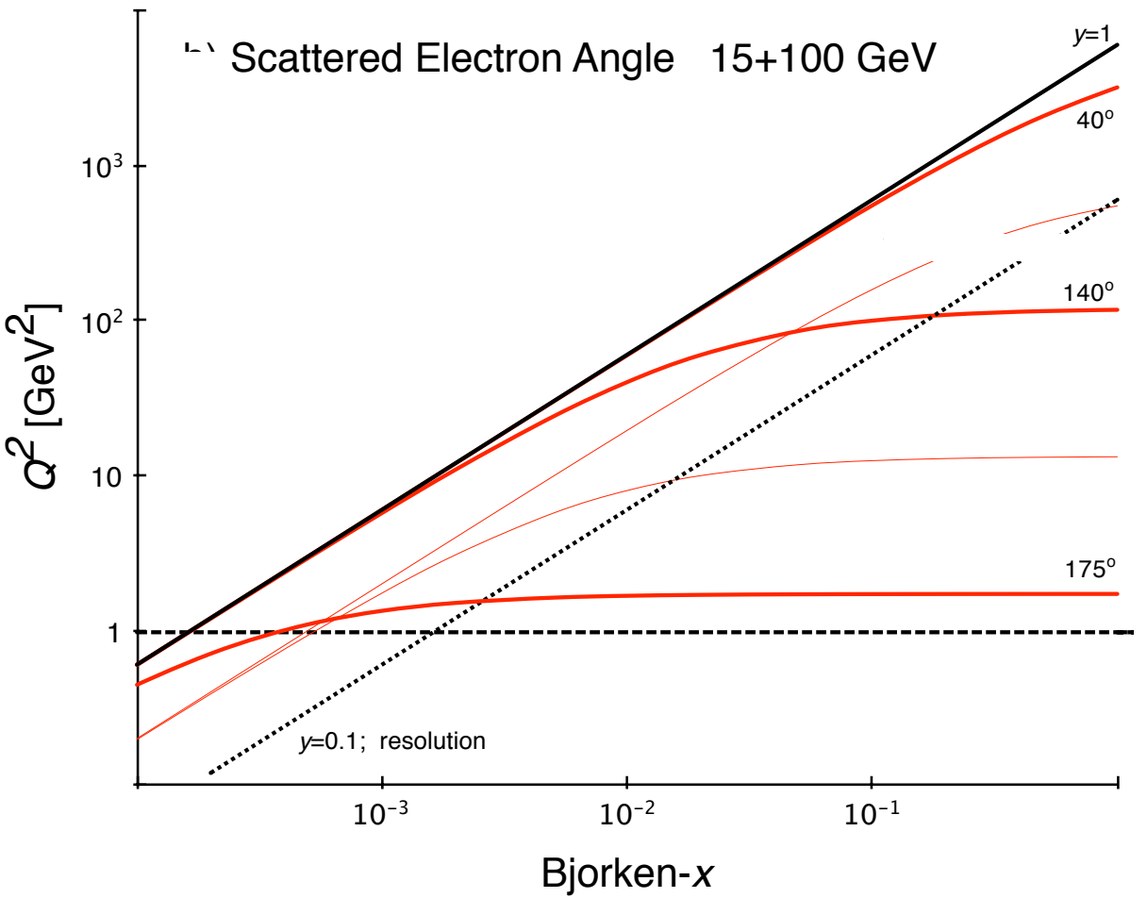
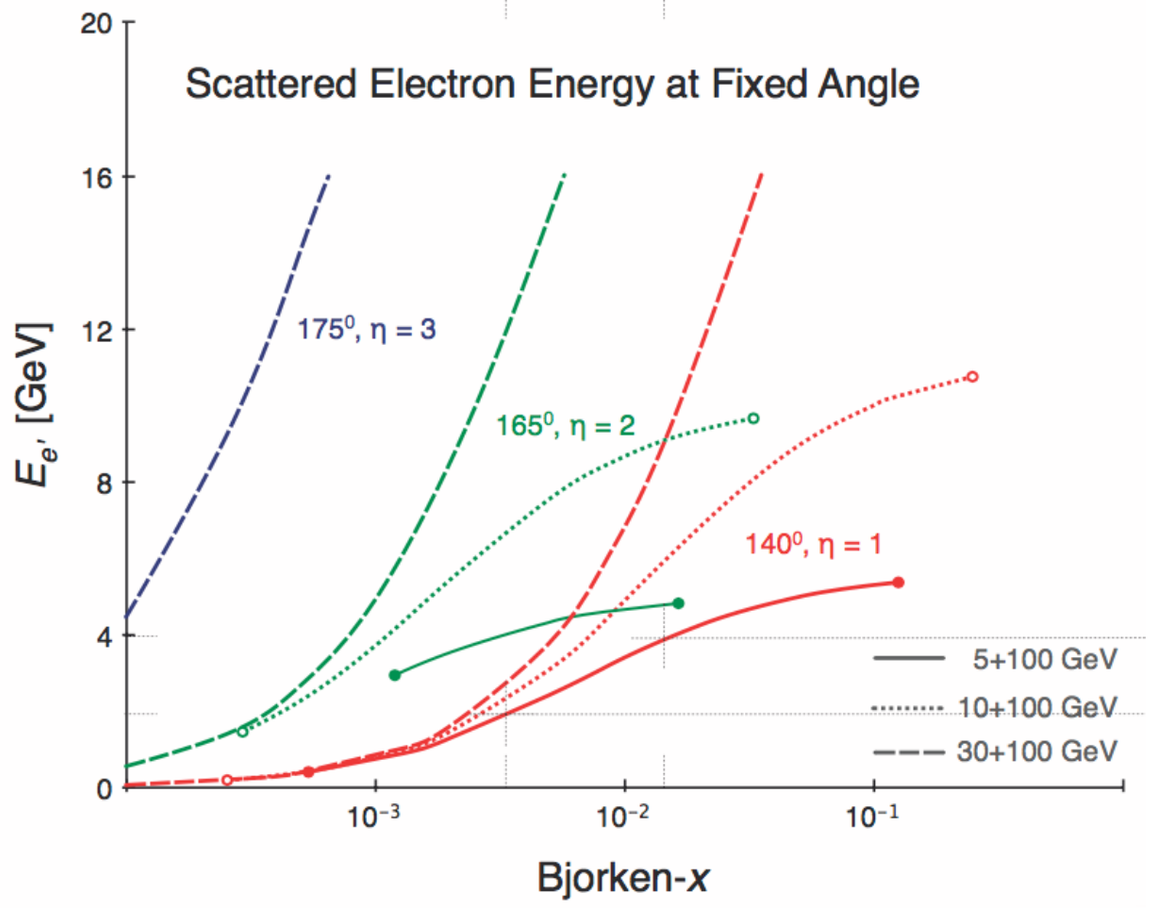




necessitates instrumentation at *backward* angles w.r.t. the hadron beam (HERA convention),

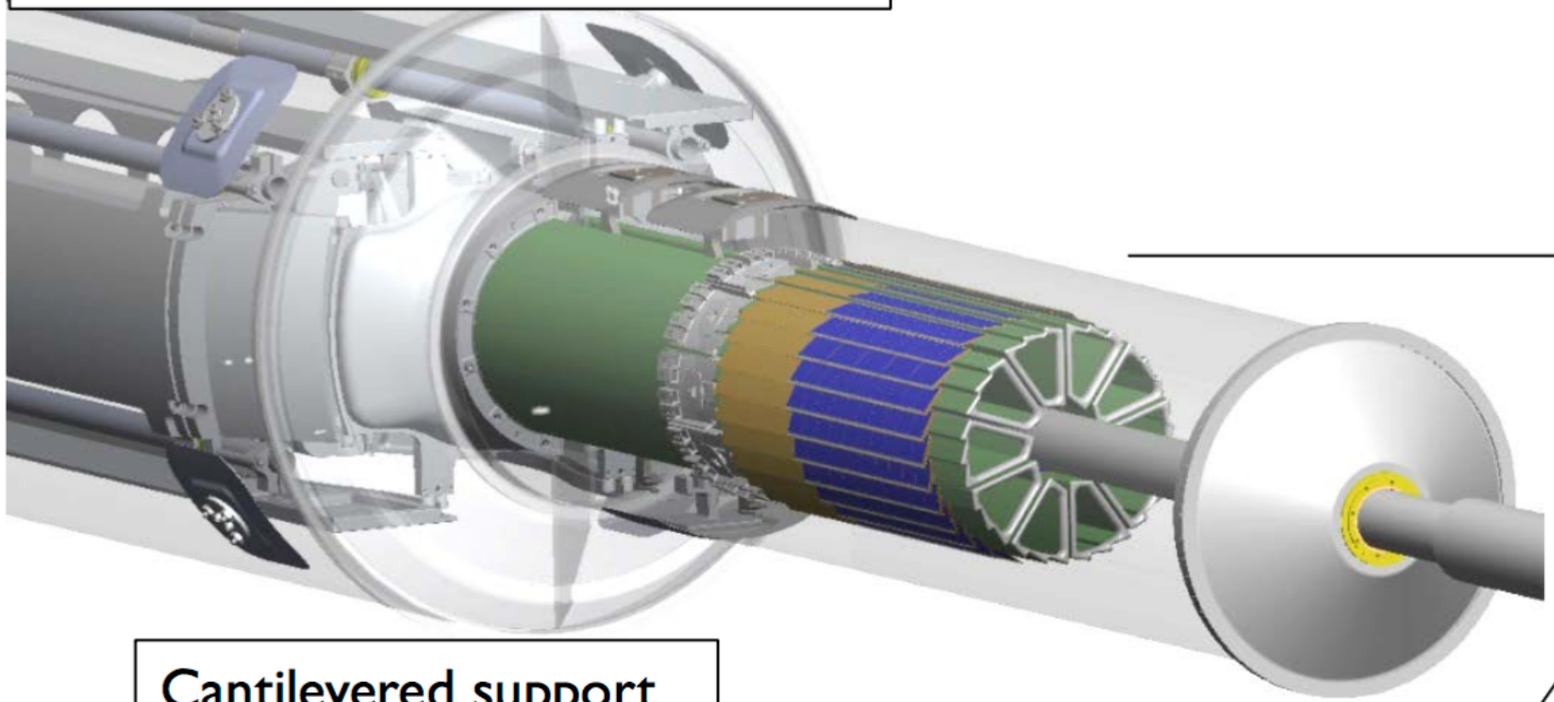
semi-inclusive observables do so at *forward* angles.

RNC - STAR HFT-PXL

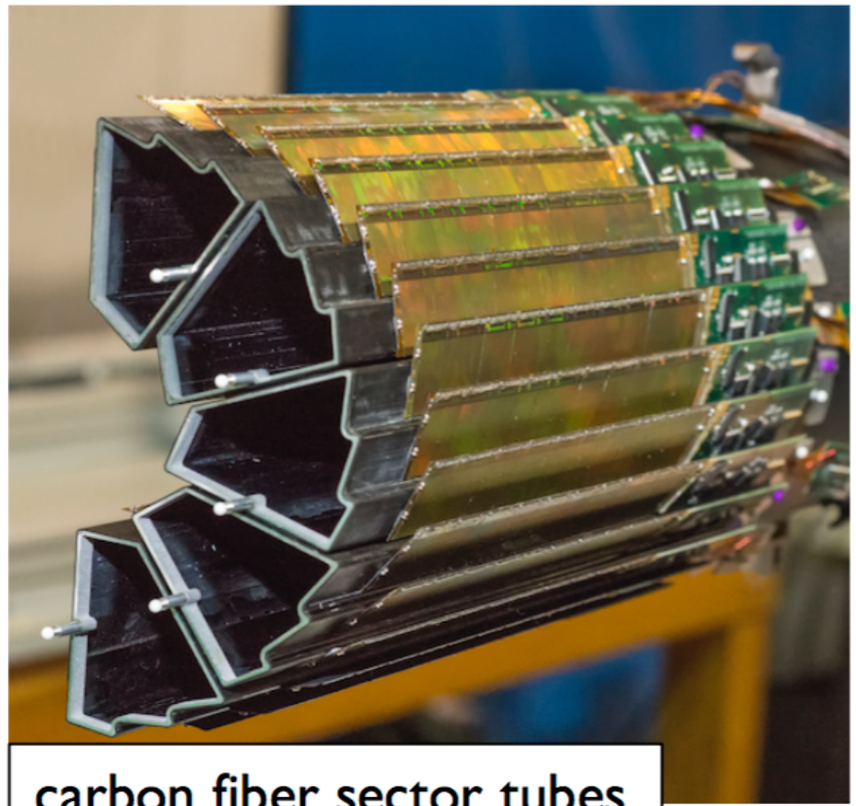
10 sectors total
5 sectors / half
4 ladders / sector
10 sensors / ladder

Highly parallel system

Mechanical support with kinematic mounts (insertion side)



Cantilevered support



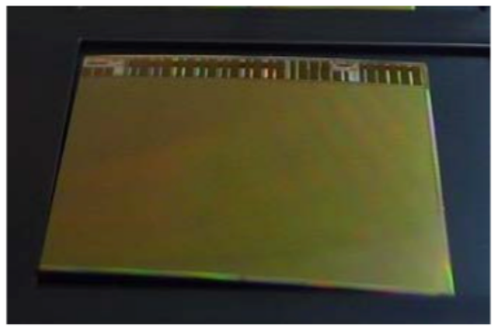
carbon fiber sector tubes
(~ 200 μm thick)

Ladder with 10 MAPS sensors (~ 2×2 cm each)

Courtesy G. Contin (LBL-RNC), for the STAR collaboration, QM2015

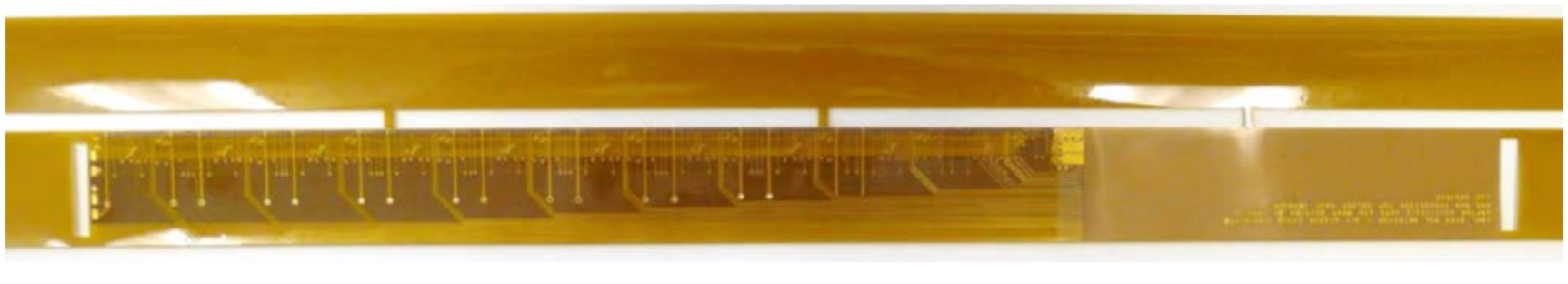
RNC - STAR HFT-PXL

- **Thinned Sensor**
  - 50 μm
  - 0.068% X_0

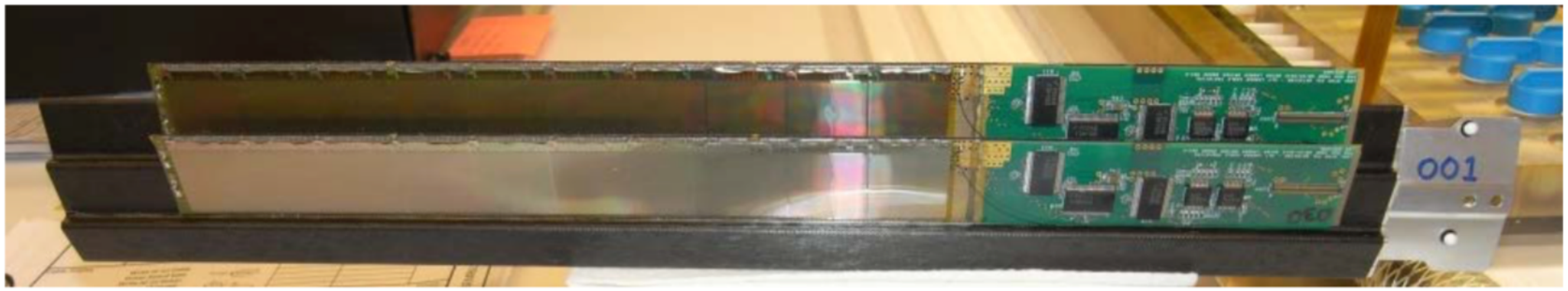


- Curved sensor
- 40-60% yield after thinning, dicing and probe testing

- **Flex Cable**
  - Aluminum-Kapton
  - two 32 μm-thick Al layers
  - 0.128% X_0
    - *Copper* version → 0.232% X_0



- **Carbon fiber supports**
  - 125 μm stiffener
  - 250 μm sector tube
  - 0.193% X_0



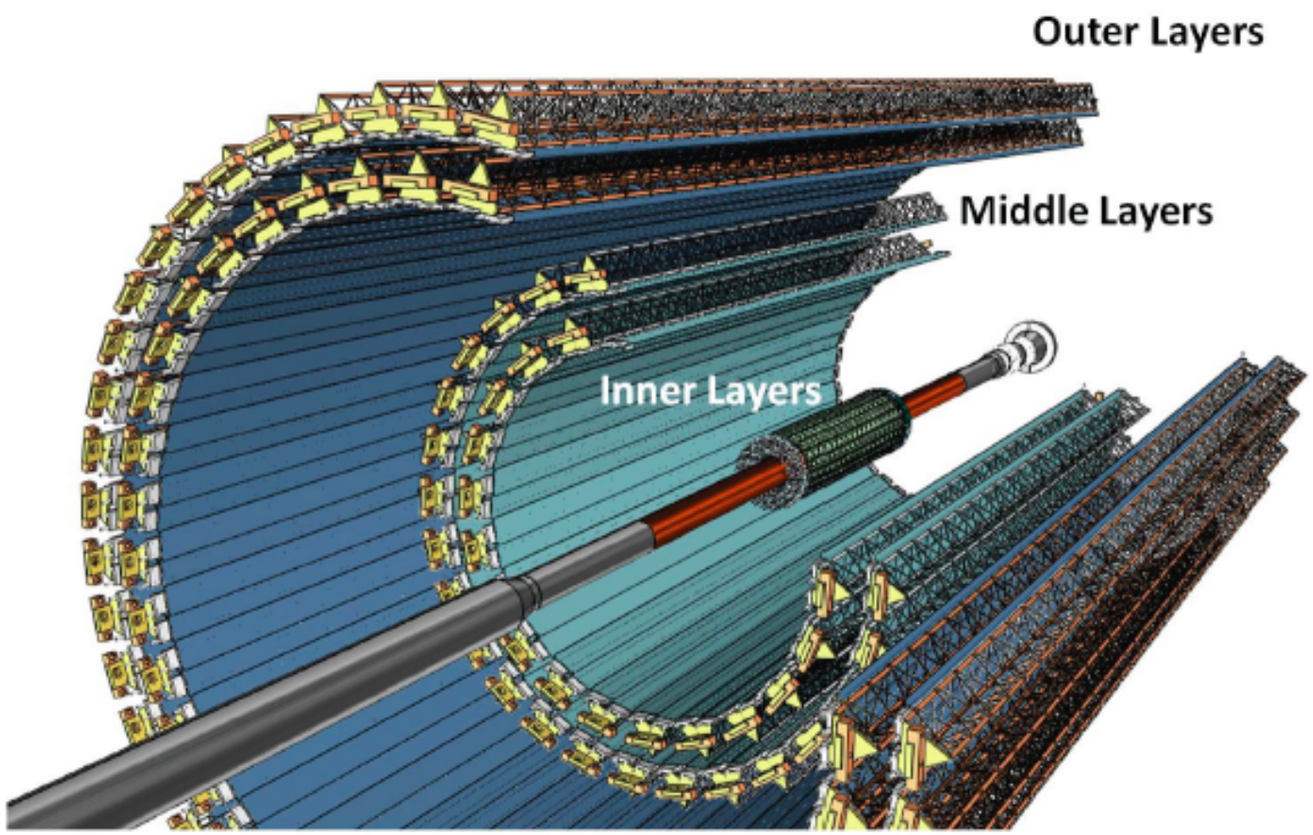
- **Cooling**
  - Air cooling: negligible contribution

- **Total material budget on inner layer: 0.388% X_0**

(0.492% X_0 for the Cu conductor version)

Courtesy G. Contin (LBL-RNC), for the STAR collaboration, QM2015

RNC - ALICE ITS Upgrade



- 7 layers
- 10 m^2 of silicon
- Installation in early 2019
- X/X_0 ~ 0.3% (inner layers)
- X/X_0 ~ 0.8% (outer layers)

Anticipated use of CERN-developed MAPS sensors, ALPIDE:

Dimensions:	15mm x 30mm
Pixel pitch:	28µm x 28µm
Integration time:	approx. 4 µs
Power consumption:	39mW/cm^2

TDR: http://iopscience.iop.org/0954-3899/41/8/087002/

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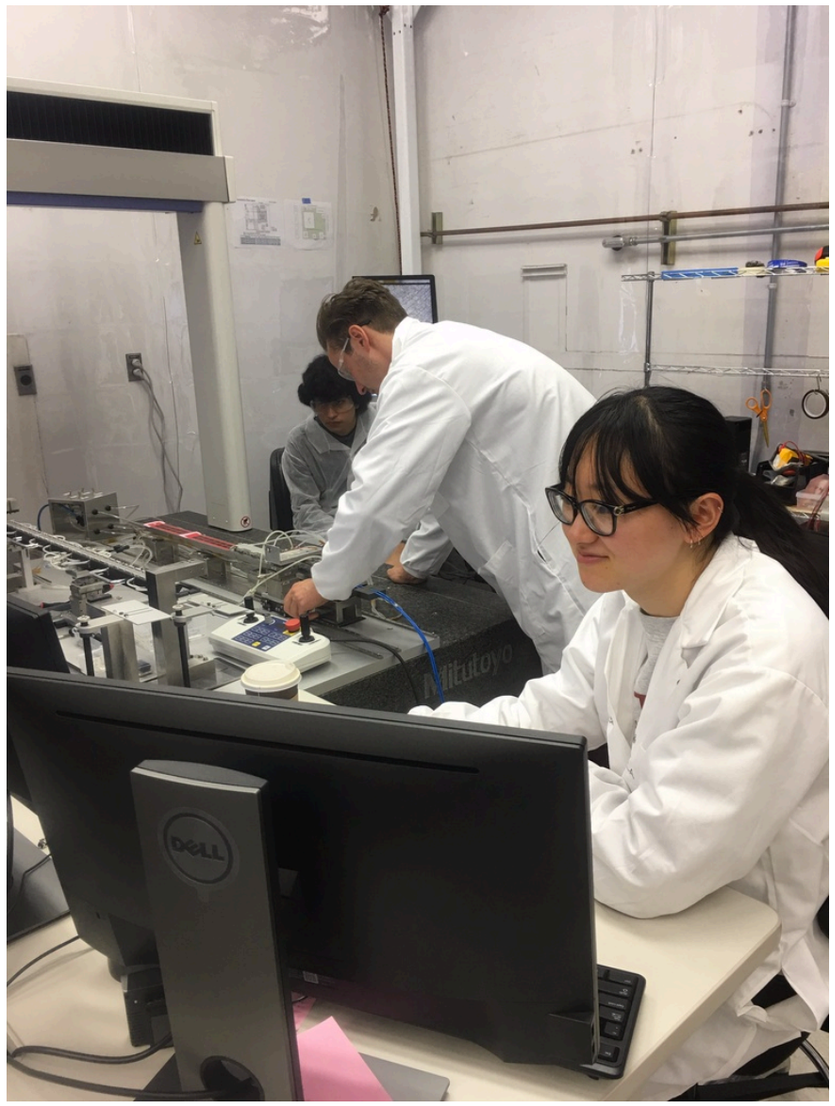

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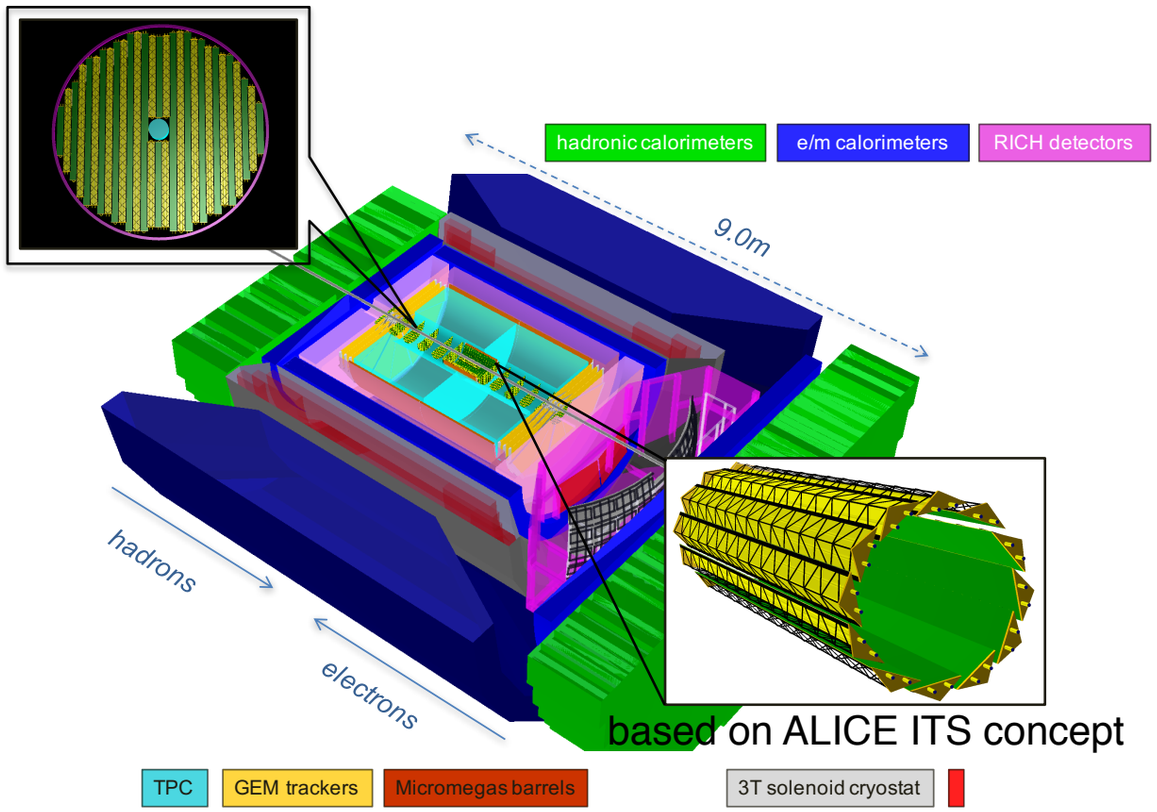
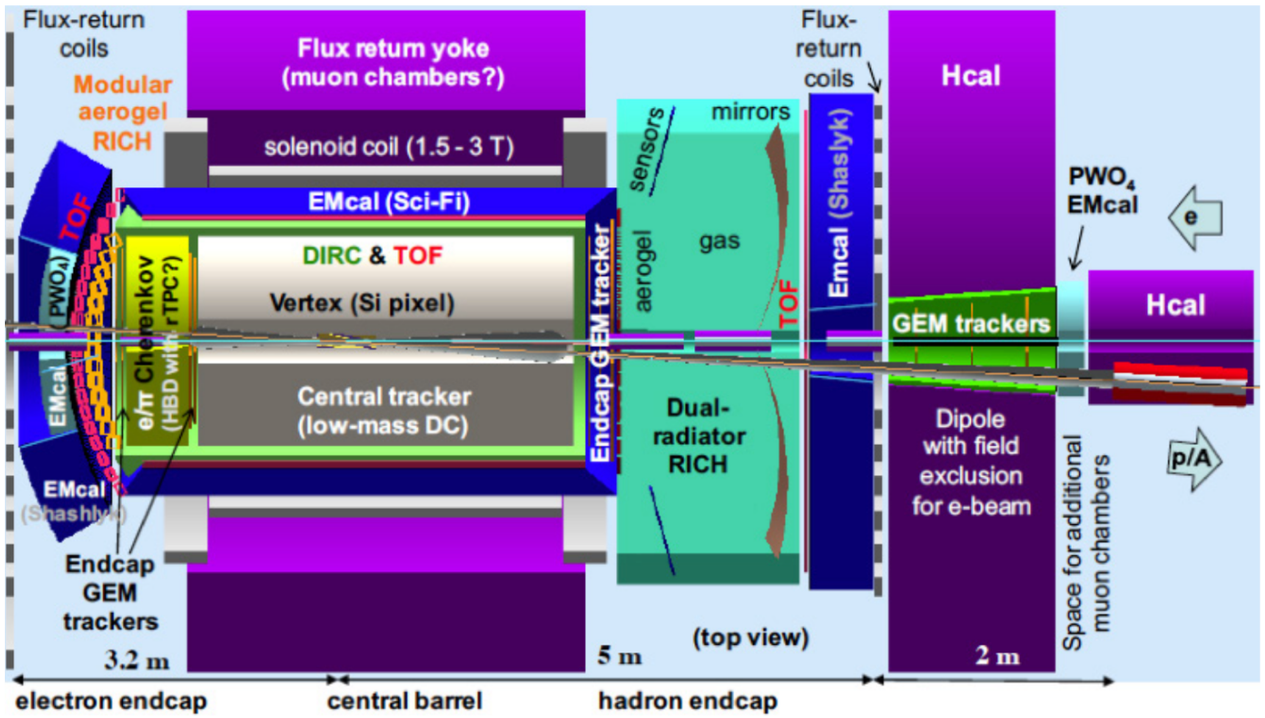
ALICE ITS is in production.

Vertex tracker for sPHENIX being proposed.

EIC Detector Concepts*



BeAST concept



JLEIC detector concept

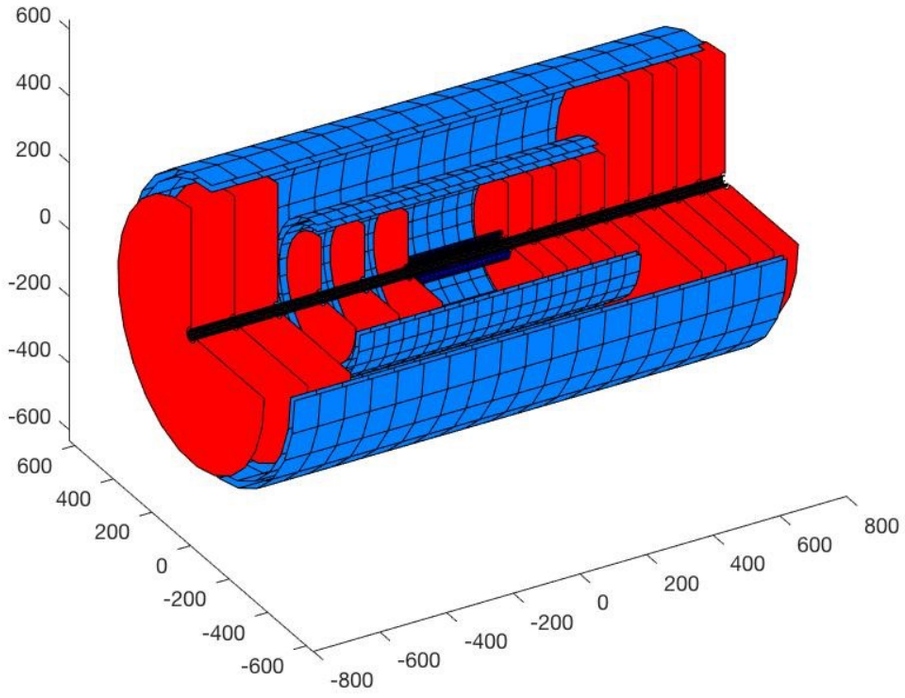
Si-based *inner* tracking and vertex detectors*, covering central and forward regions, for eRHIC as well as JLEIC detector concepts,

EIC needs: large acceptance, low mass, and high resolution.

*Other concepts exist; e.g. J. Repond et al. have put forward an all-Si tracker
All-Si detector concepts have thus far been mostly outside the scope of our R&D.

eRD16 - EIC R&D Simulations

- Charged-particle tracking toolset originally developed for ILC studies by the Vienna group, M. Regler, M. Valentan, and R. Frühwirth (2008):
  - Helix track model,
  - Multiple scattering,
  - Full track reconstruction from digitized hits using a Kalman filter.



Hypothetical all-Si tracker in a 1.5T Solenoidal field.

- Rapid studies of number of layers, disks, geometrical layout, etc.

- Work done with UCB undergraduate students Ivan Velkovsky, Winston DeGraw, and most recently with SBU undergraduate student Emily Biermann.

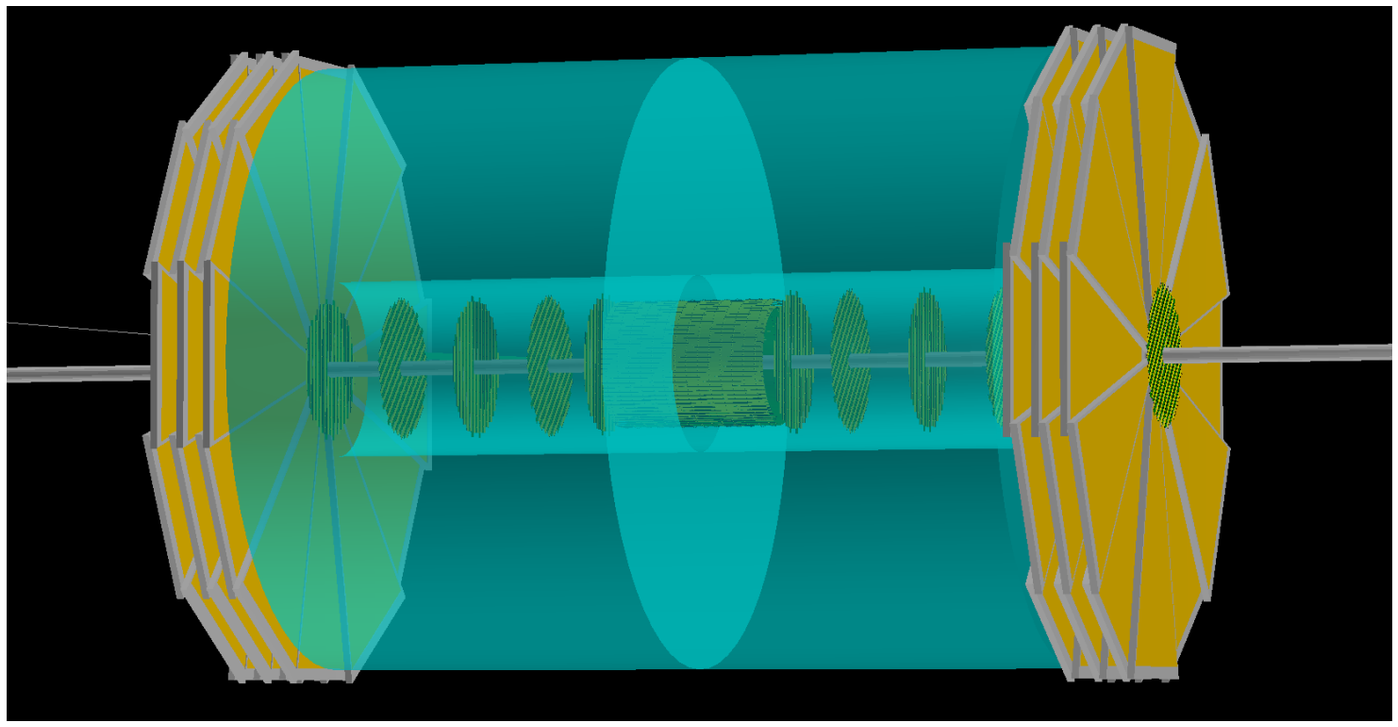
eRD16 - EIC R&D Simulations

- Toolset(s) developed by EIC task-force at BNL;

  EICRoot; GEANT-based simulations

  Pythia-eRHIC,

  (EIC-smear)



BeAST; seen are the TPC, Si-barrel and disks, and large-area GEMs

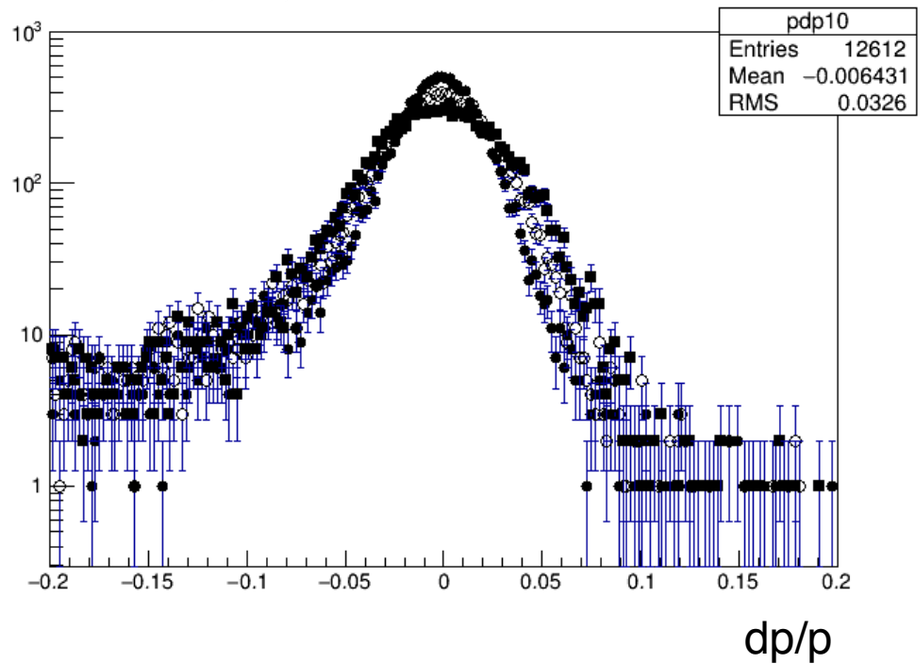
- Work done by Yue Shi Lai, and ongoing to
  confirm/refute key findings from fast simulations,
  changes to improve geometry and infrastructure,
  currently also UCB graduate student Ezra Lesser.

- Preferred toolset going forward, as the issues need more realistic answers, and for collaboration with eRD18.

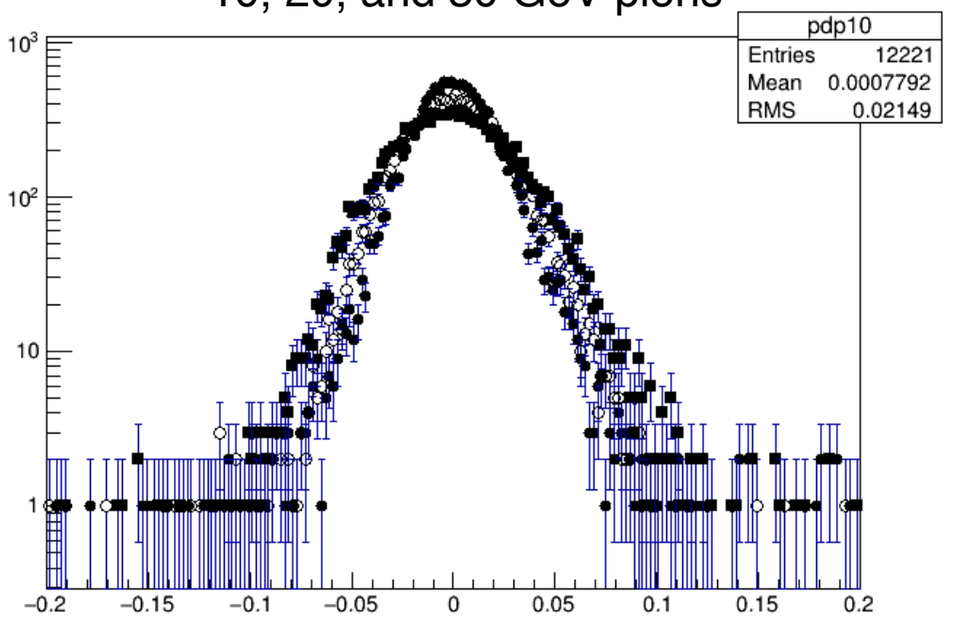
eRD16 - EIC R&D Simulations

- For example,

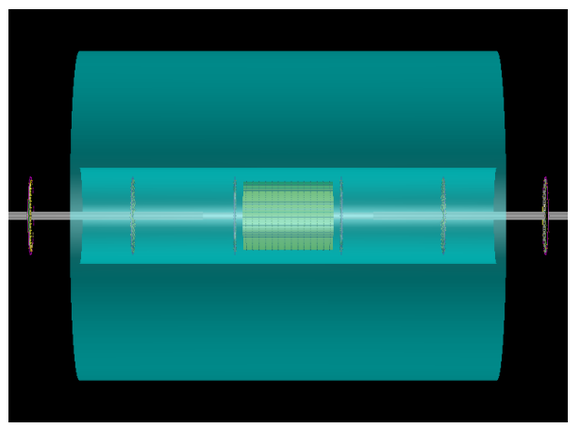
10, 20, and 30 GeV electrons



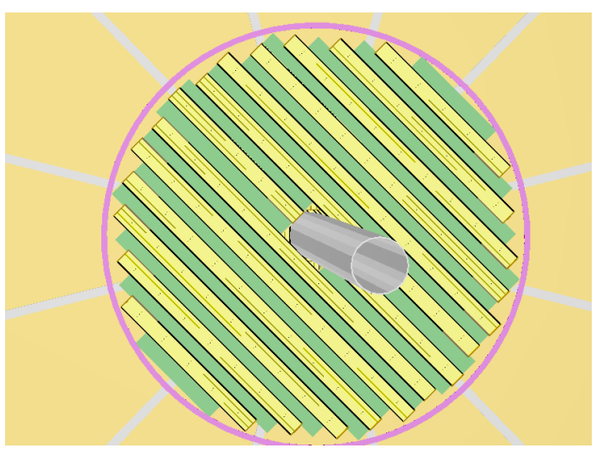
10, 20, and 30 GeV pions



Tails (can/do) matter, even in a 3-disk simulation.

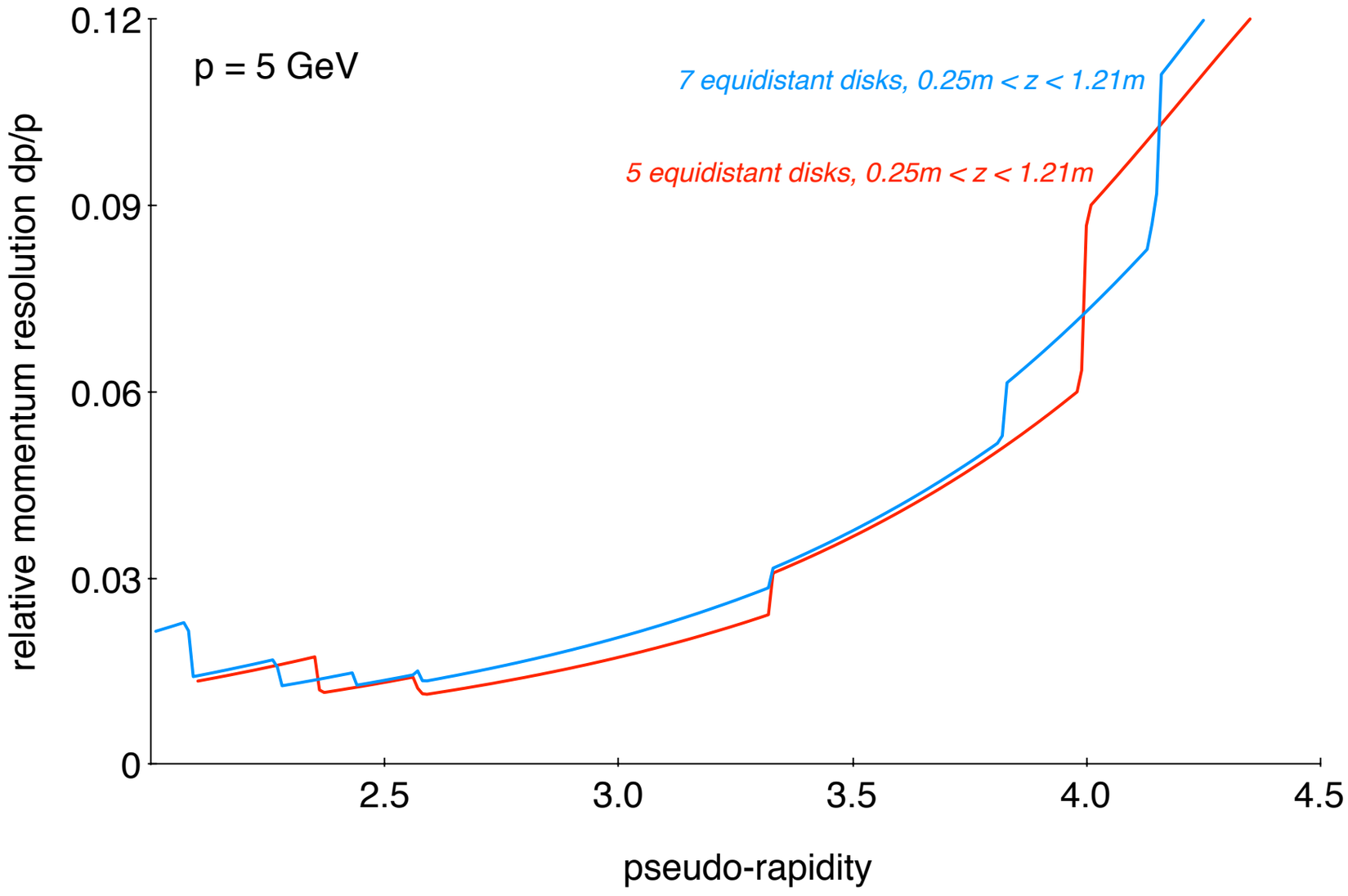


- Towards supports and (other) infrastructure.



eRD16 - EIC R&D Simulations

Fine-binned LDT results for disks in a 3T field (BeAST):



Affected by dip-angle and curvature measurement (20μm pixels), acceptance (18mm inner radii and 185mm out radii), positions (disks are equidistant in *z*; nominal collision vertex), traversed material (0.3% beam-pipe, 0.3% for each disk).

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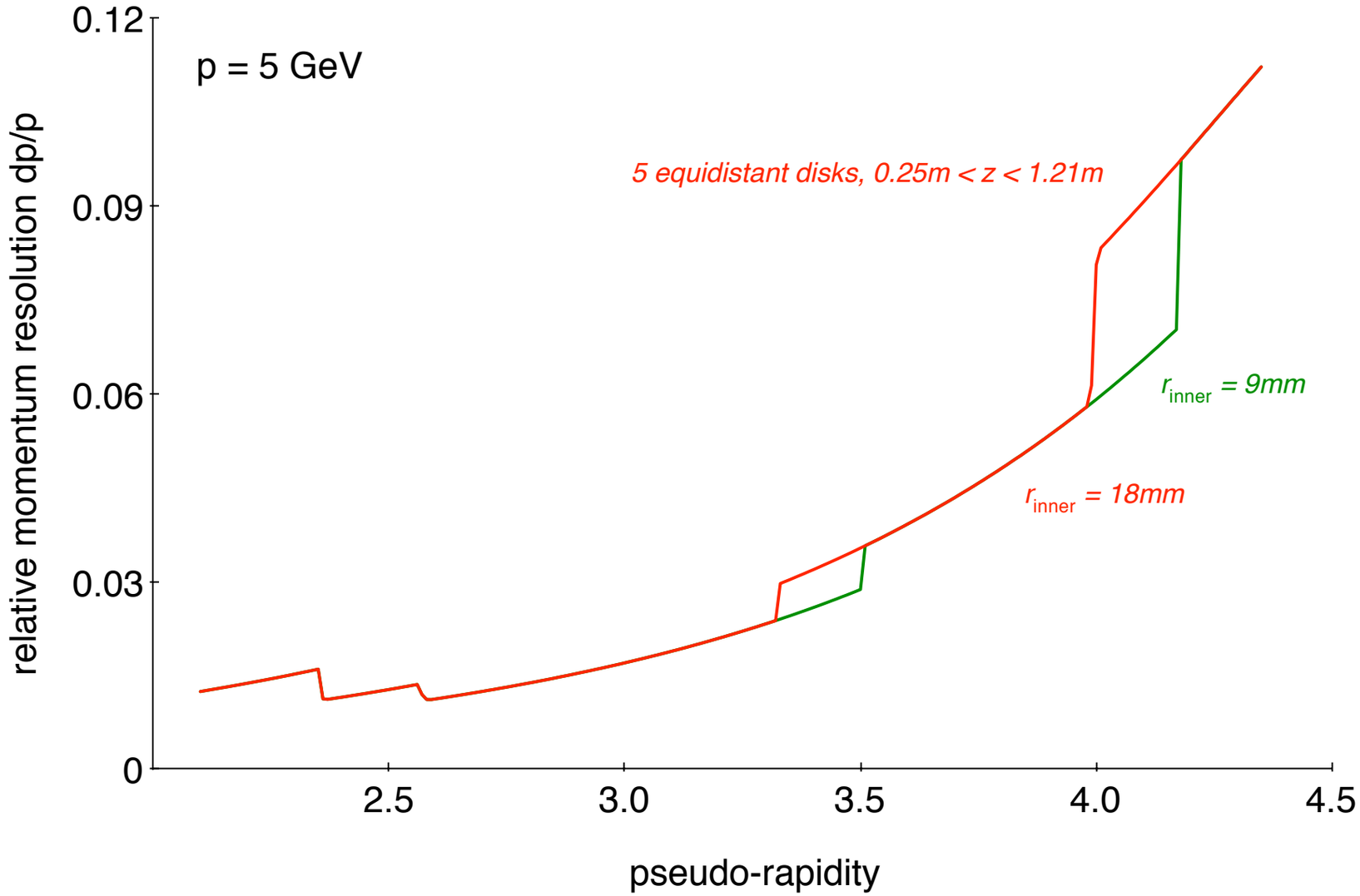

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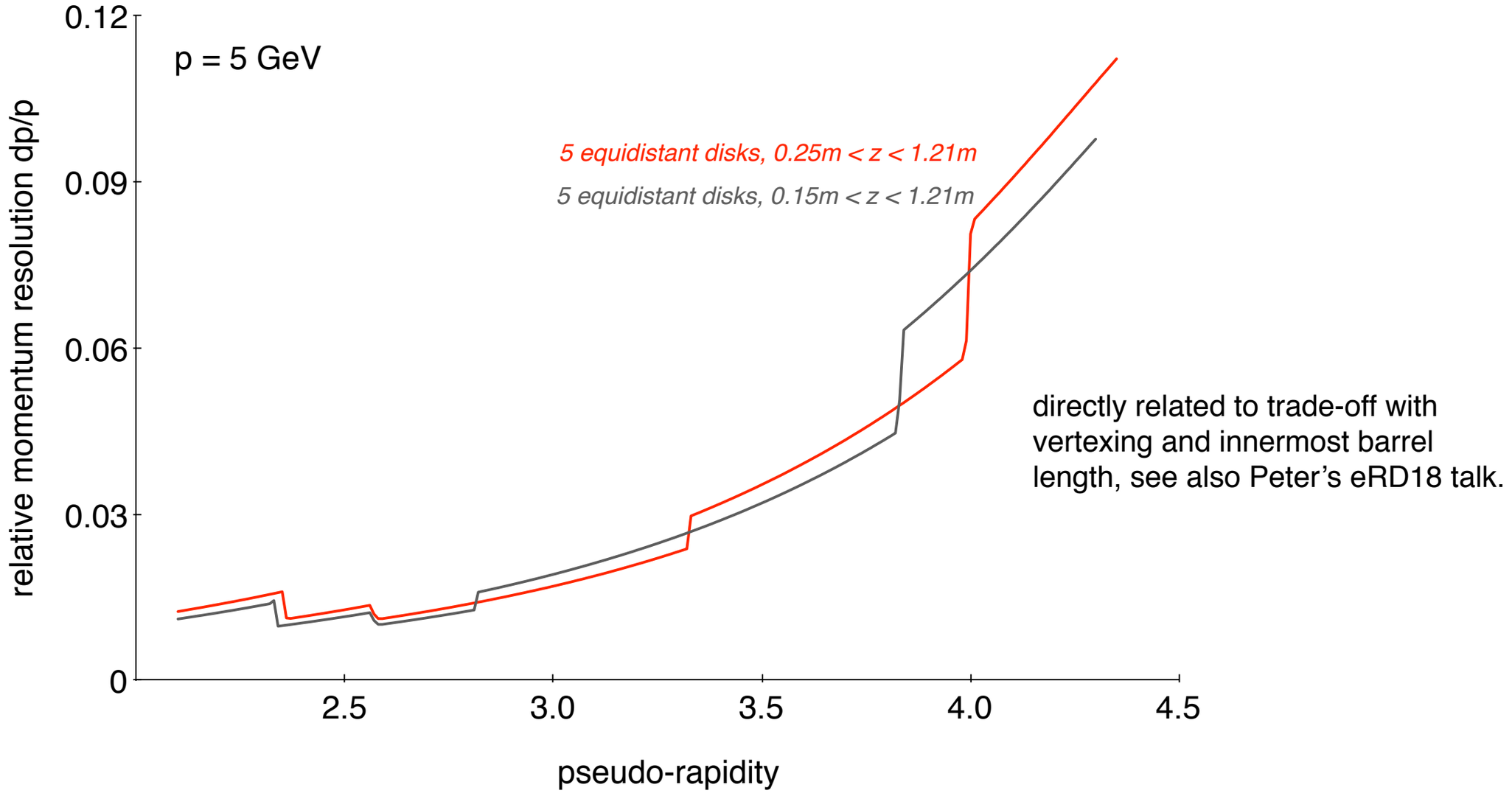

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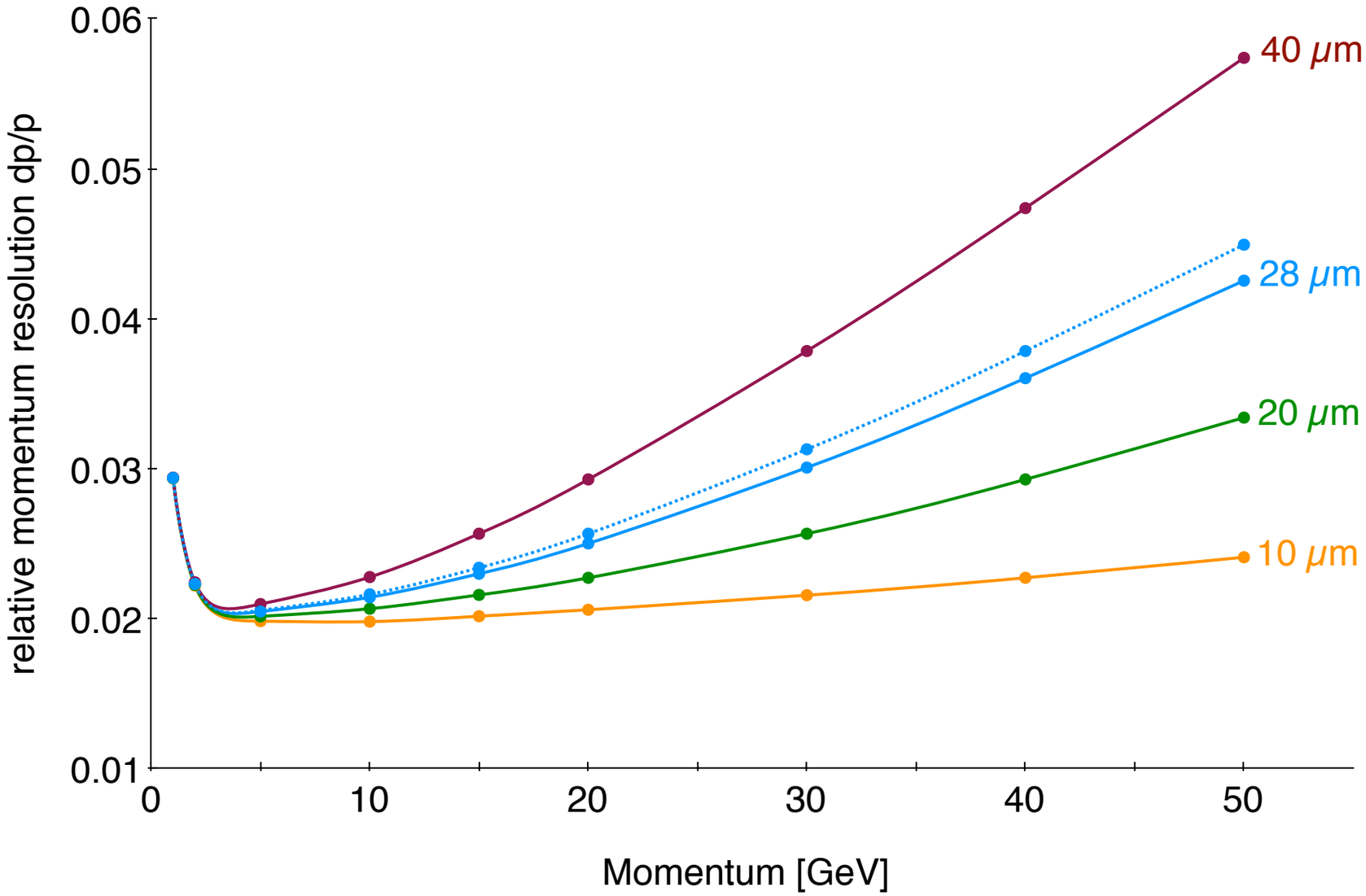
eRD16 - EIC R&D Simulations

LDT scan of pixel-size; 7 equidistant disks in a 3T field (BeAST):

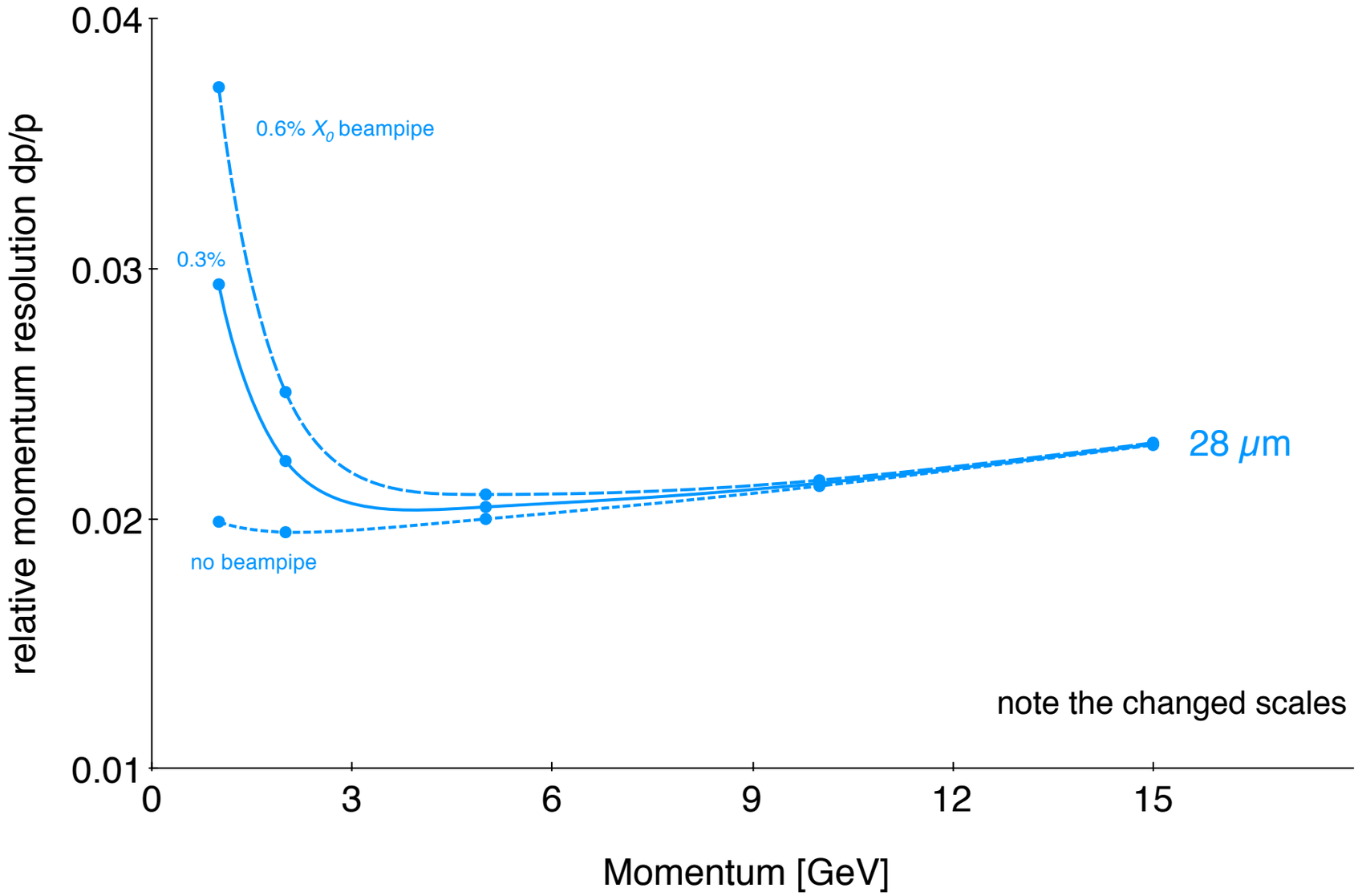


Pseudo-rapidity is 3 here; measurements from all disks,

Momentum is *inside* the beam-pipe here; upturn at low (absolute) momentum originates mostly with uncertainty in the dip-angle,

eRD16 - EIC R&D Simulations

LDT scan of pixel-size; 7 equidistant disks in a 3T field (BeAST):



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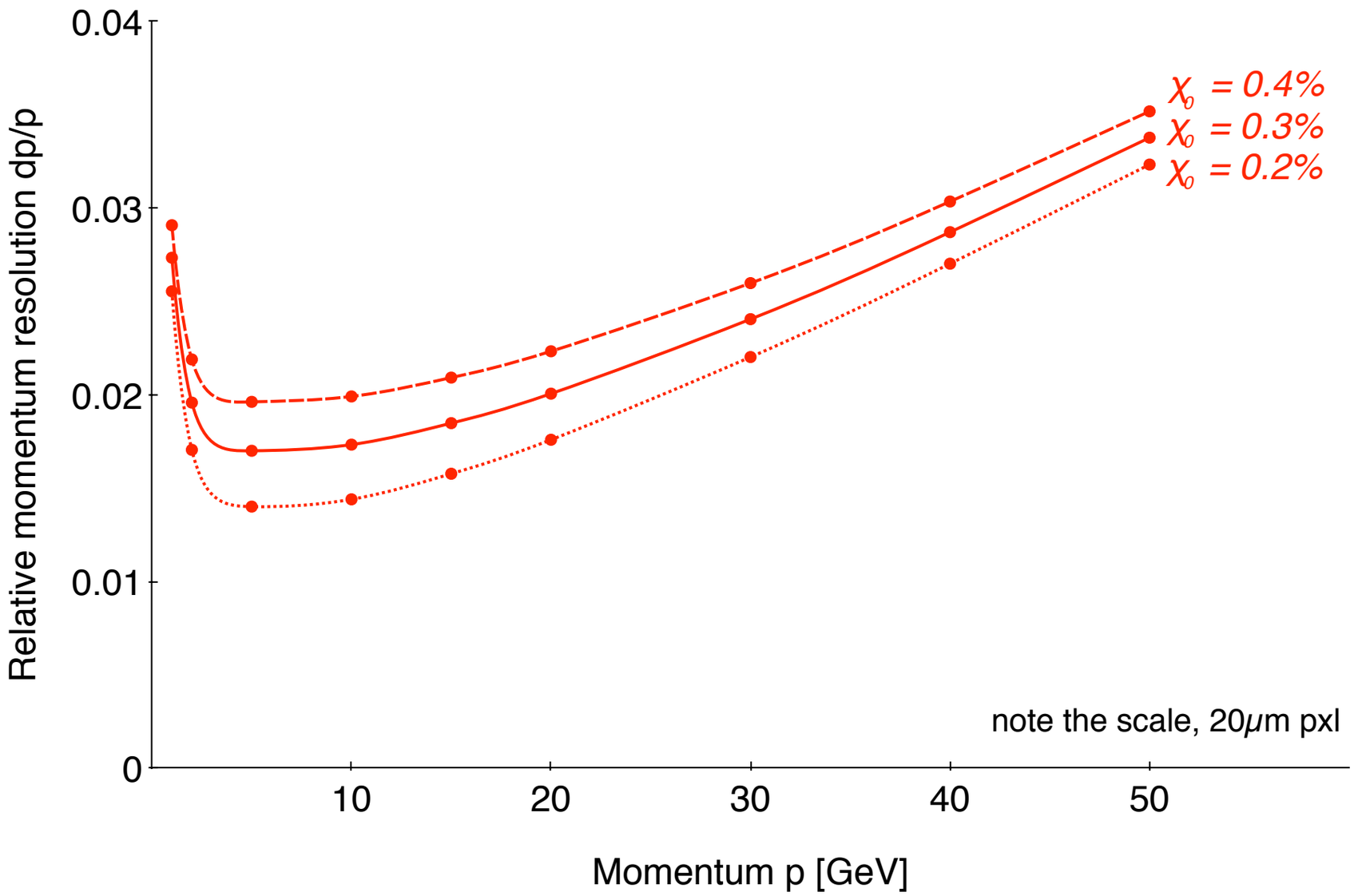

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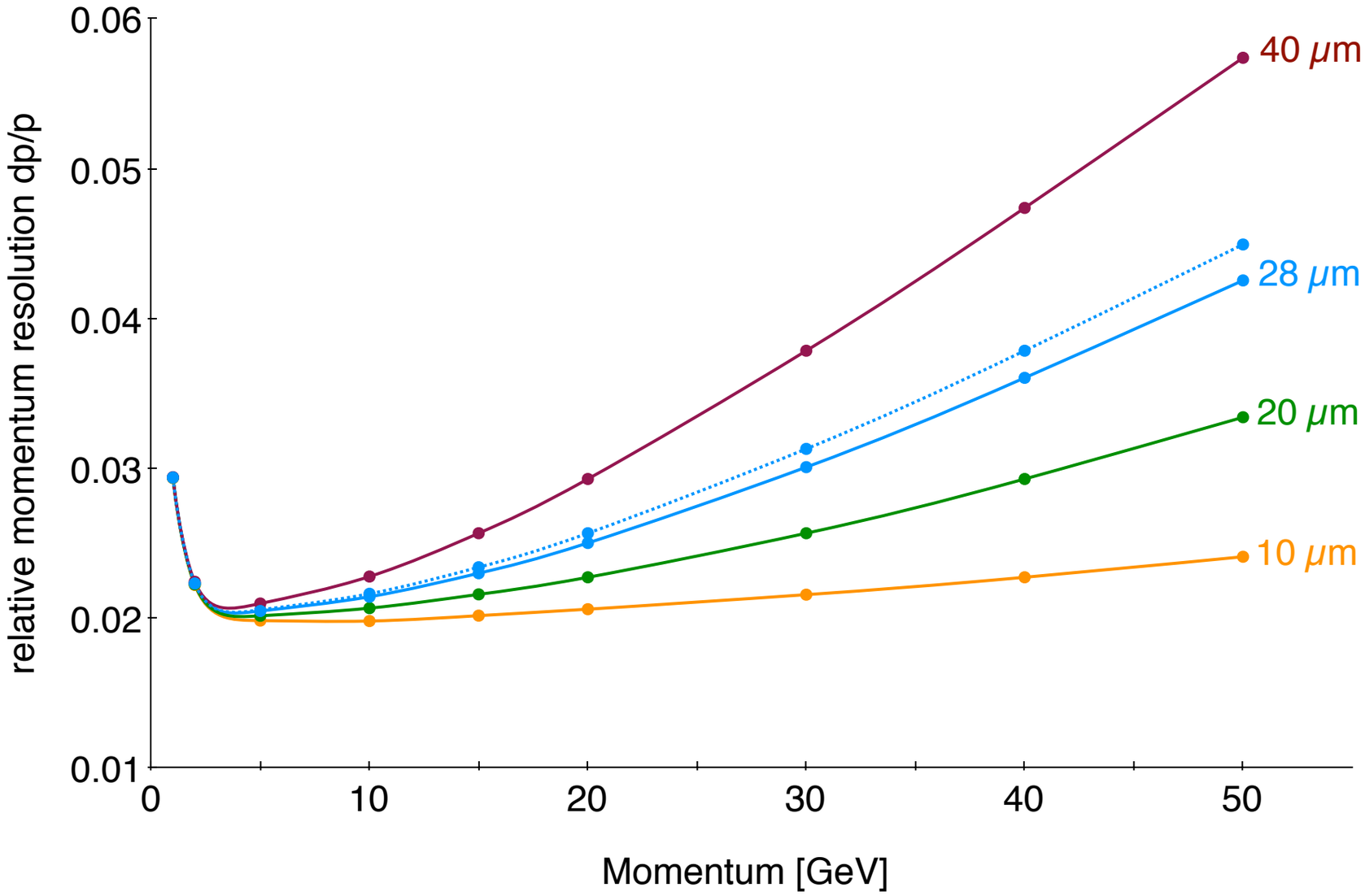

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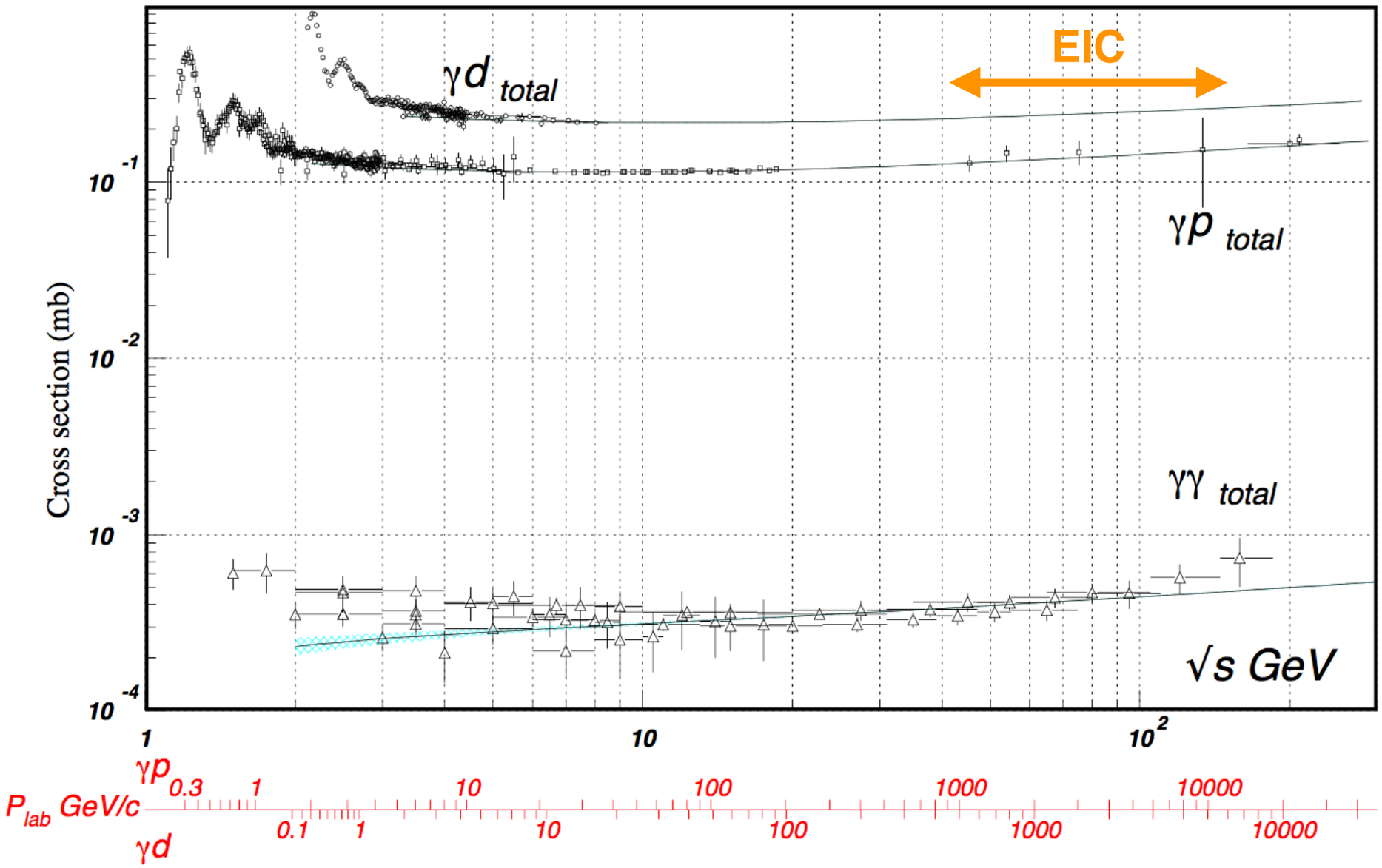
Momentum is *inside* the beam-pipe here; upturn at low (absolute) momentum originates mostly with uncertainty in the dip-angle,

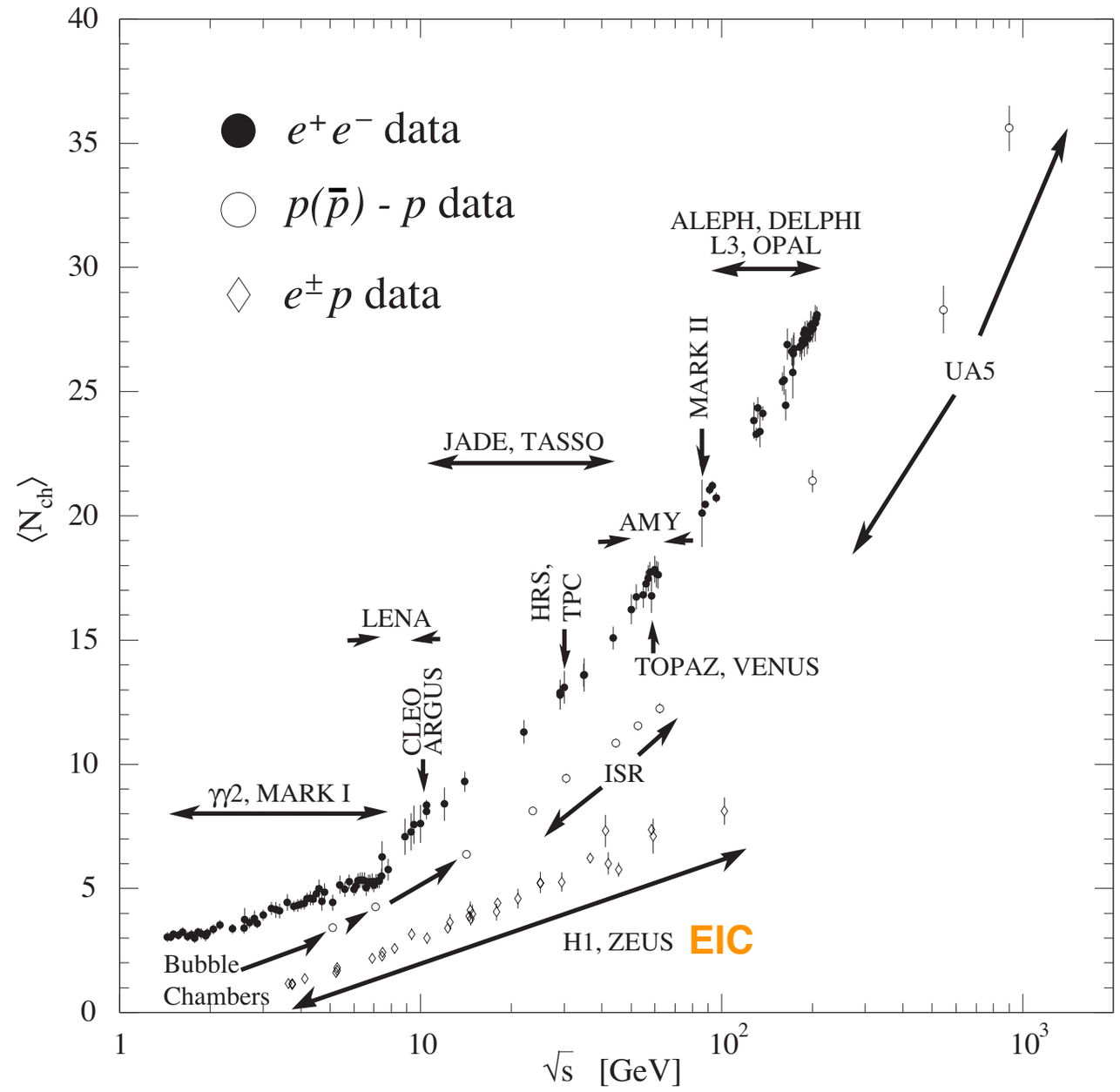
~20μm pixel size is reasonable in this application, as is 0.3% thickness per disk

EIC - Rates



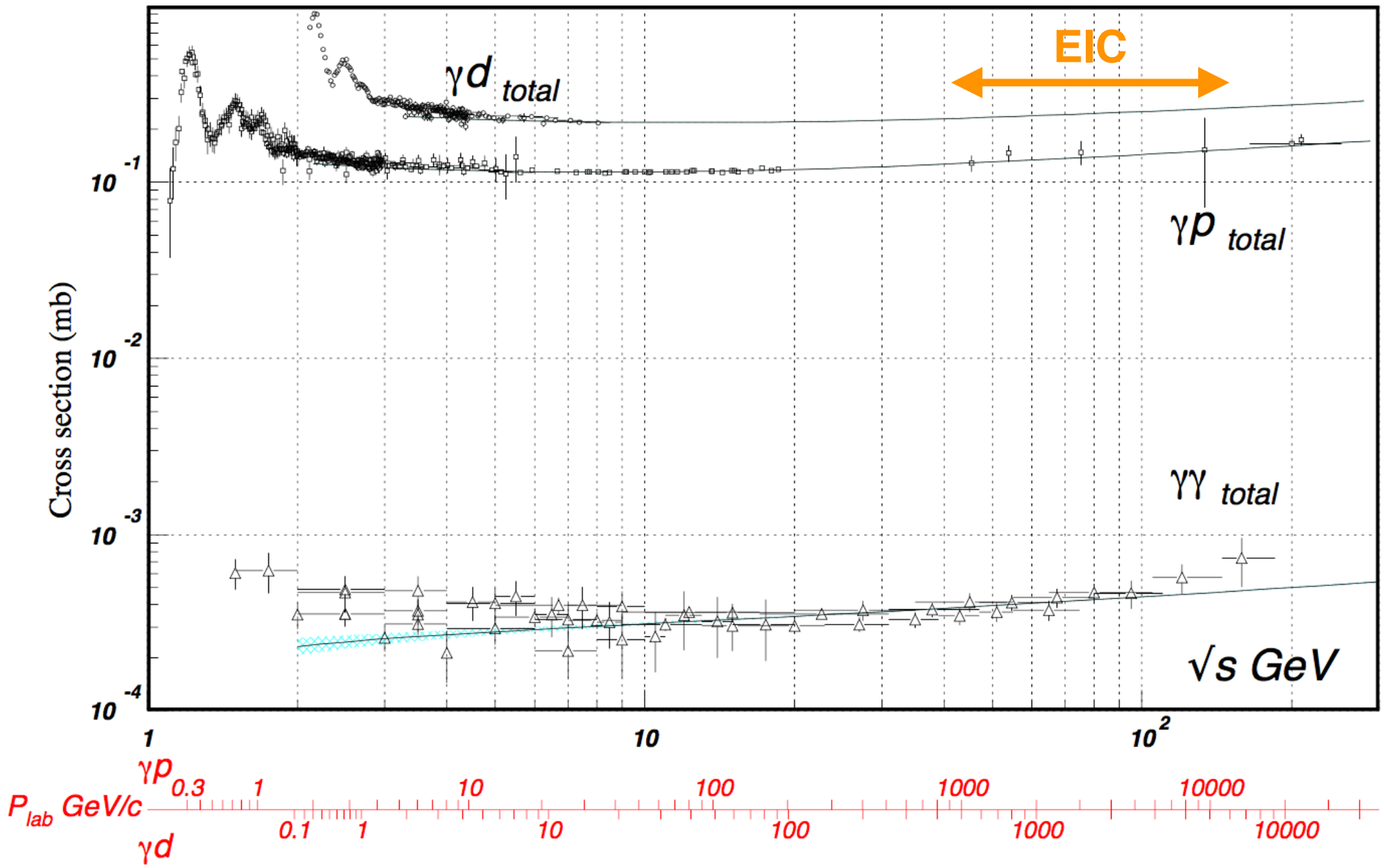
Photoproduction is the dominant cross-section; well known,
2 orders below RHIC, LHC

EIC - Rates



Likewise, particle multiplicities are well below those at the hadron colliders,

EIC - Rates



L ~ $10^{33(34)}$cm^{-2}s^{-1} implies a ~50 (500) kHz collision-event rate,

<< EIC bunch cross crossing rate

~ similar to μs integration times

eRD16 - EIC R&D Simulations

Initial considerations of timing and rates,

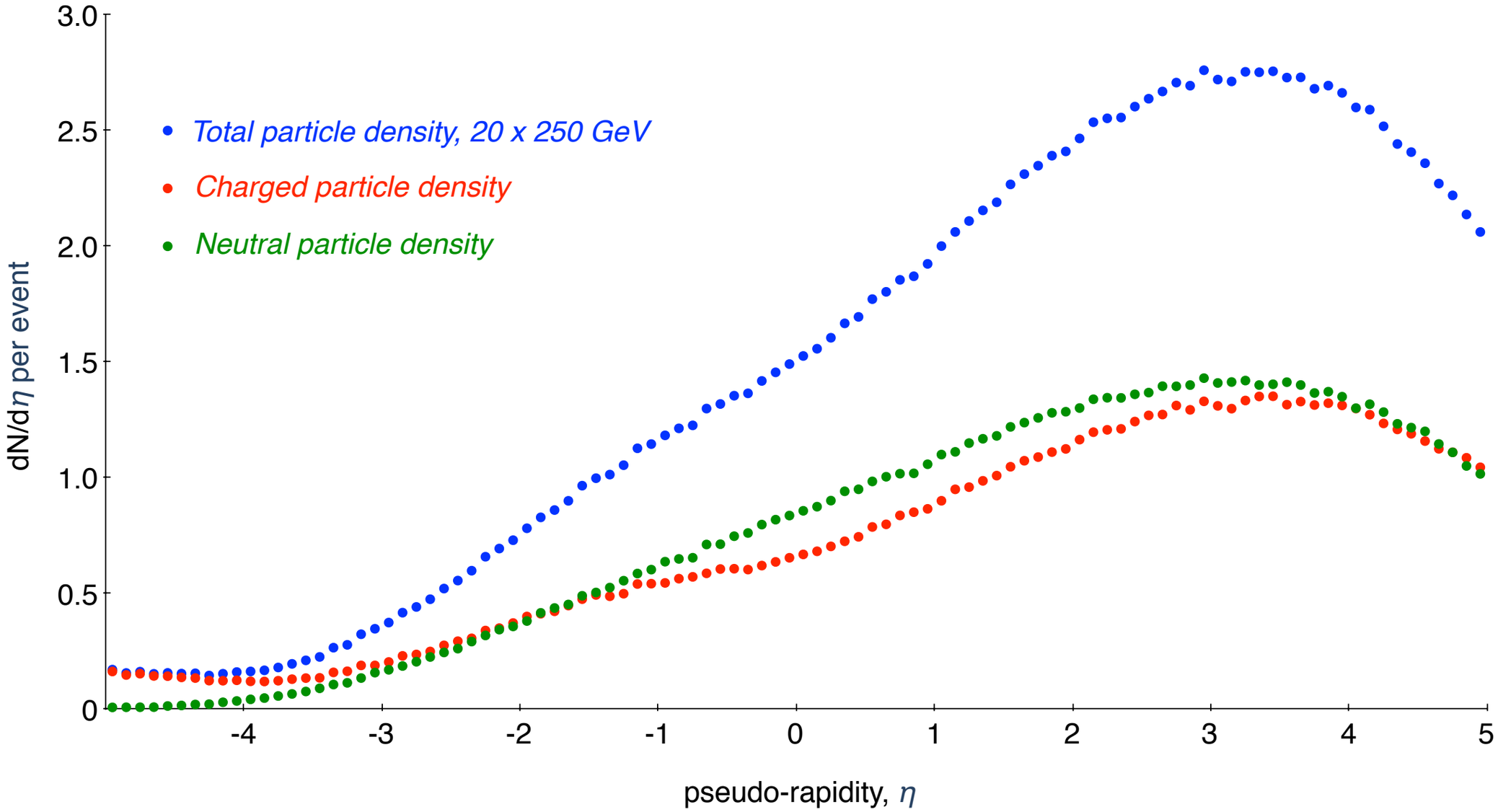
- eRHIC: 10 MHz beam bunch repetition rate, or higher (100ns separation, or less),
  JLEIC: 476 MHz (2.1ns),
- Not every bunch crossing produces a collision,
- The track density in a typical collision is modest; few tracks are produced,
- Tracks and events need to be associated with each other and
  with the beam-crossing (spin config.)
- Implications for EIC Si sensors and fast tracking layers*?

* TPC has proven to be much more involved; effort stopped.

eRD16 - EIC R&D Simulations

Initial considerations of timing and rates,

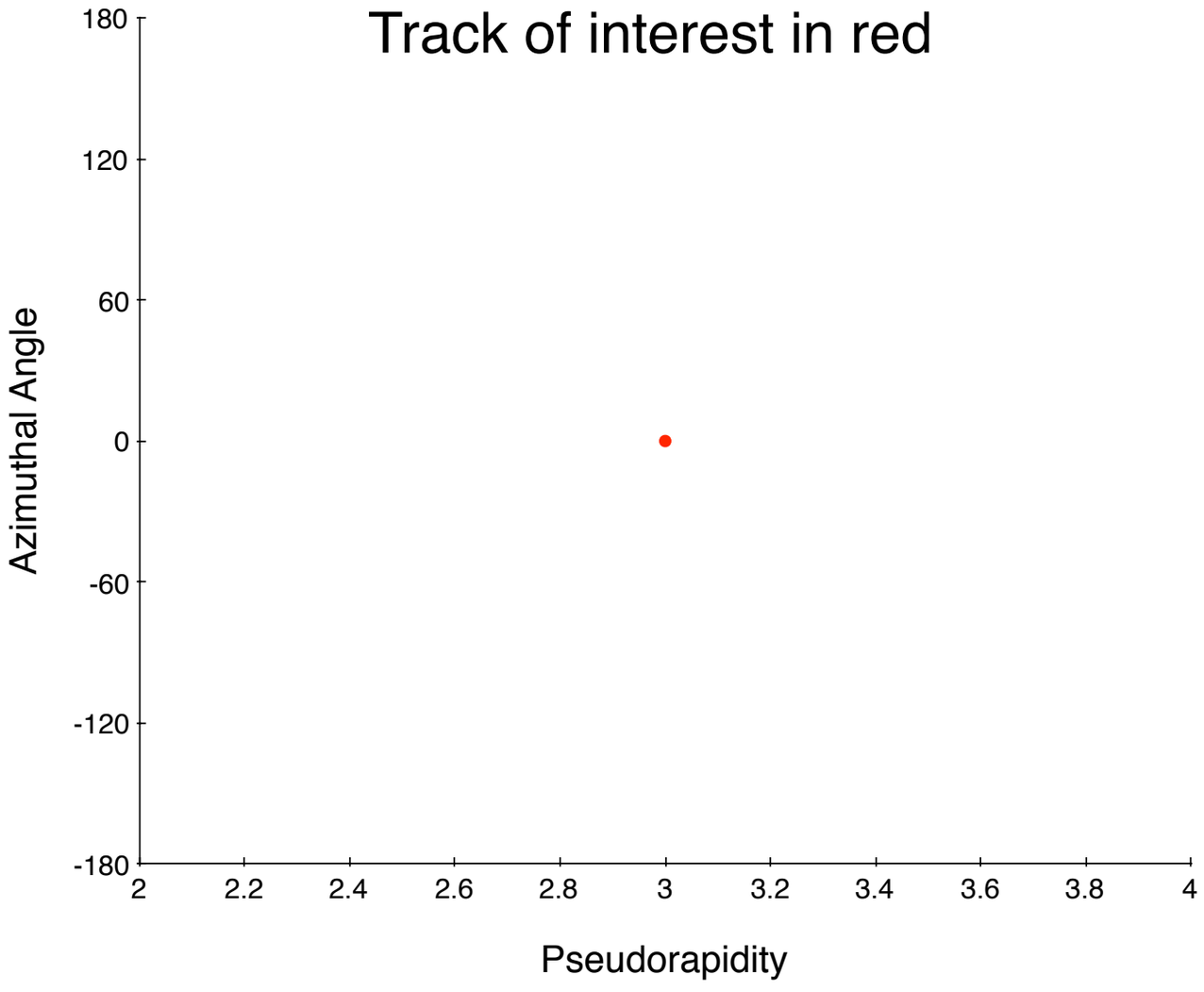
PythiaeRHIC simulations of track-densities for *charged* particles



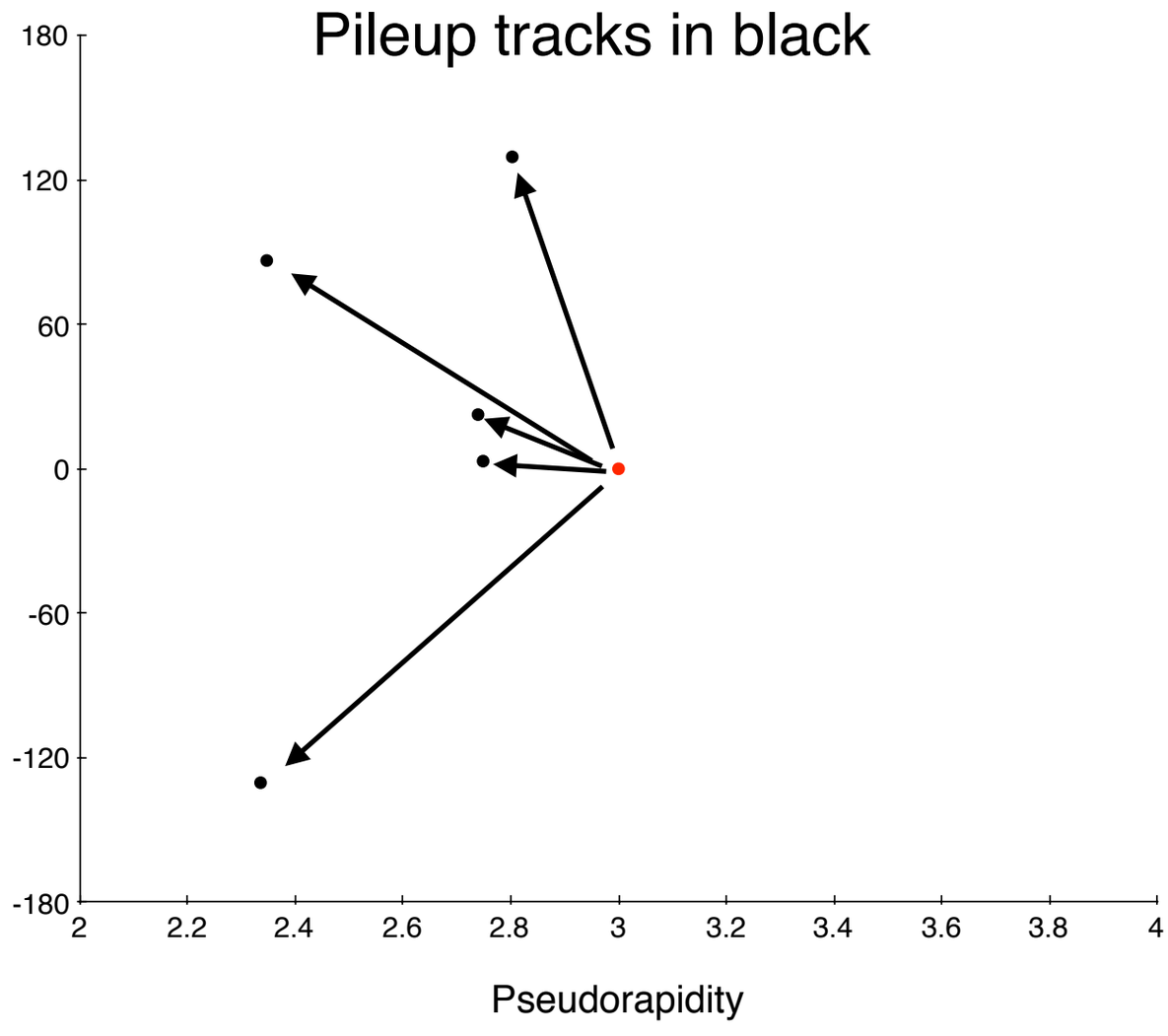
eRD16 - EIC R&D Simulations

Initial considerations of track/event pileup in Si-sensors

Track of interest in red



Pileup tracks in black



Here, L ~ $10^{33}cm^{-2}s^{-1}$, event pileup probability 0.04/μs, 10μs integration,

eRD16 - EIC R&D Simulations

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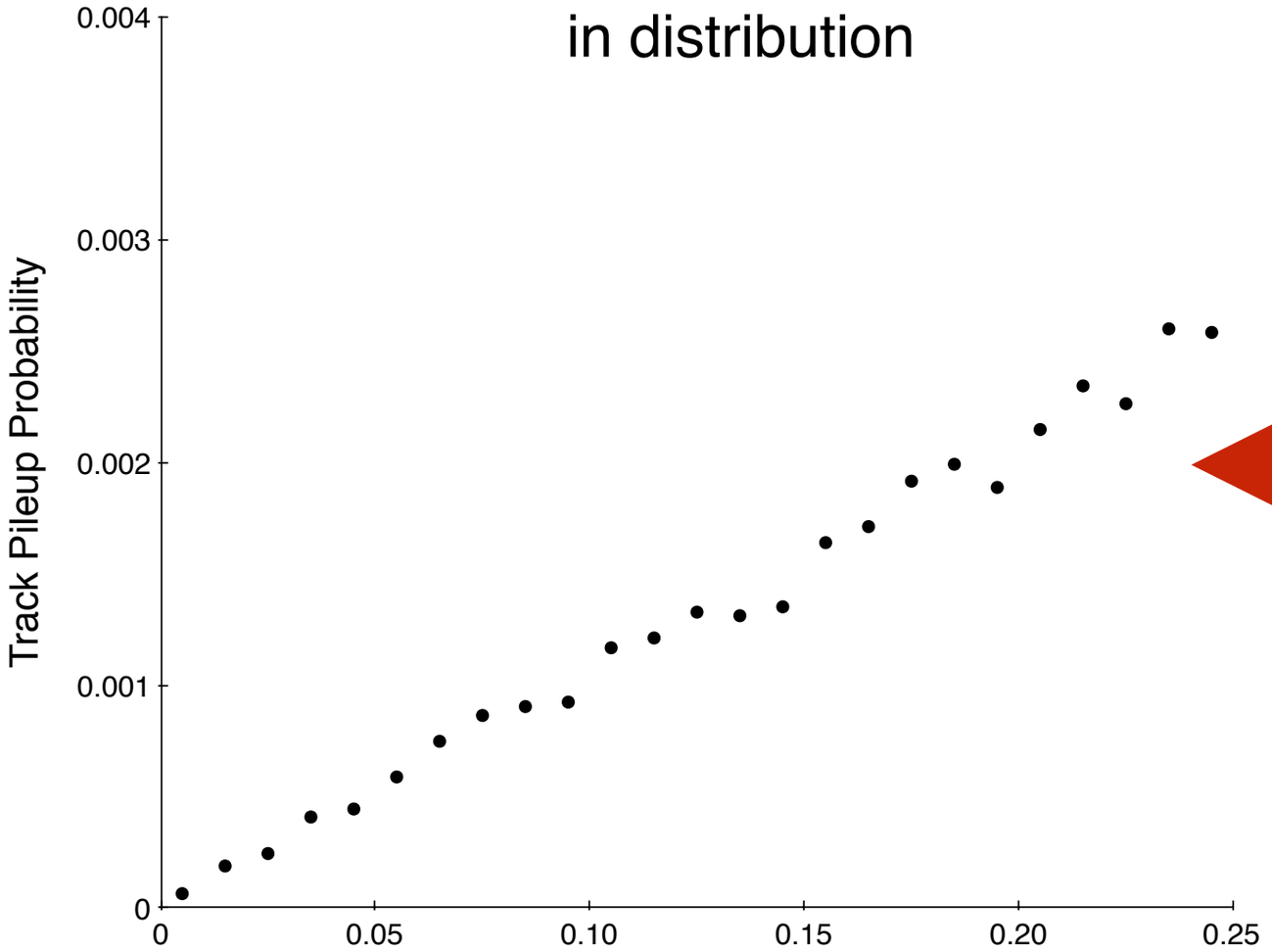

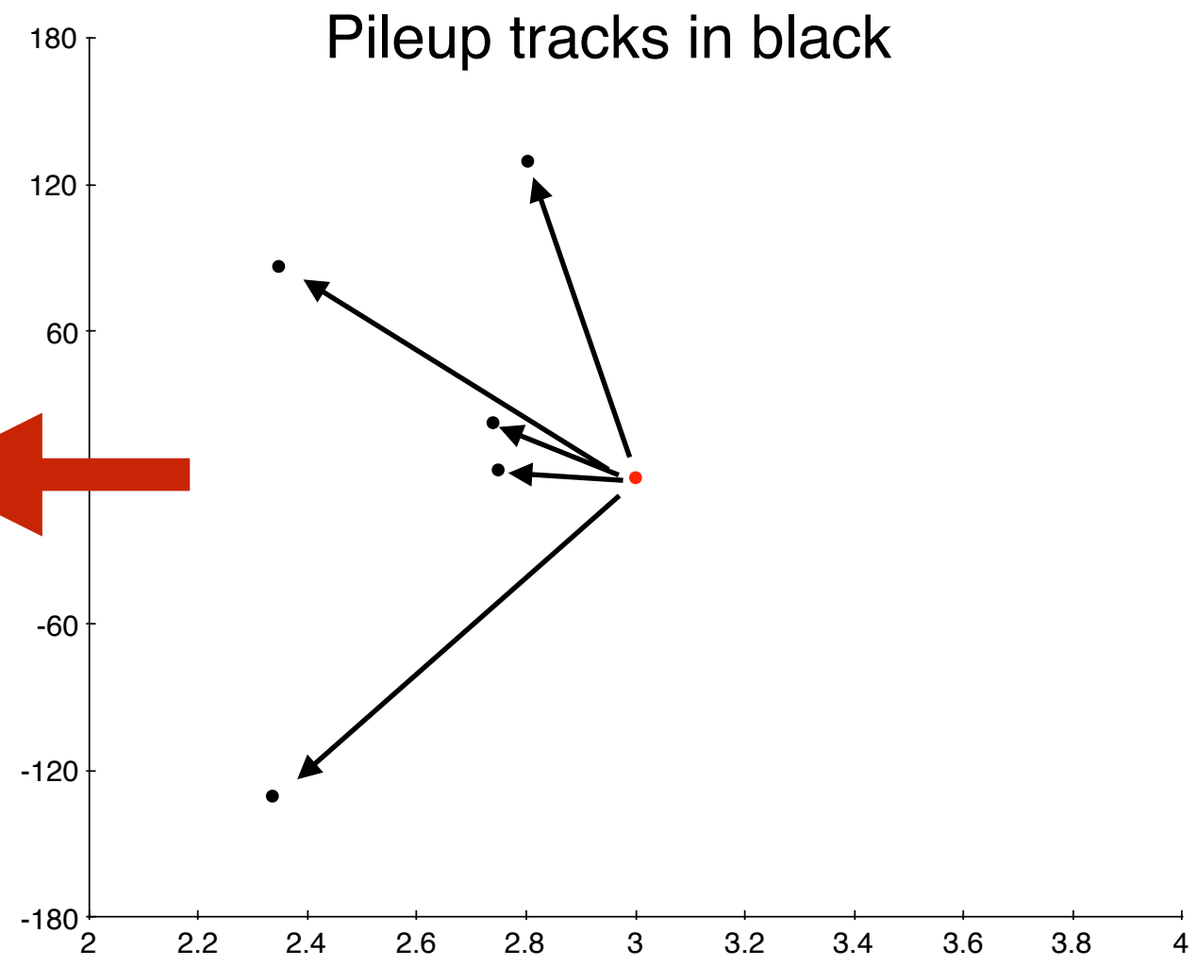

Here, L ~ $10^{33}cm^{-2}s^{-1}$, event pileup probability 0.04/μs, 10μs integration,

Simple anchoring to a fast(er) point,

1mm resolution at 1m corresponds to ~0.01 in R for eta~3,

~1 μs integration time seems reasonable (timestamps not considered here/yet),

eRD16 - Proposed work

Simulations have given insight in geometrical layout and sensor specifications
for Si-based *inner* forward/backward trackers,
fast simulations are “ahead”, documentation still ongoing,
slow simulations will be completed with remaining resources,

For the upcoming period,

1. focus on interfacing with inner central barrel in close collaboration with eRD18; e.g. inner and outer barrel length vs. disk radius,
2. explore mechanical support concept(s) and cooling,
with science-driven simulations,
small fraction of a mechanical engineer to keep it realistic,
in collaboration with eRD18,
3. perform initial set of fast and slow simulations towards an *all*-Si tracker,

eRD16 & eRD18: continue monthly video meetings,
face-to-face meeting, and possibly a small workshop.

eRD16 - Request for FY19

Cost, including LBNL overheads:

33% postdoc	$53,417
5% engineer	$27,311
student support	$11,035
Total	$91,763

-20% scenario: reduce scope of simulations (postdoc/student),
forego cooling study (student),

-40% scenario: forego also any engineering ~advice.